An Operational Real-time Hurricane Wind Analysis System

1st Quarter Report to the Joint Hurricane Transition Center

PI: Mark Powell, NOAA Hurricane Research Division, AOML

Executive Summary

In the first quarter of this JHT project, milestones and timelines were set, training sessions were held with two NHC hurricane specialists who conducted four realtime analyses and provided several suggestions for improvements. HRD scientists conducted 64 realtime wind analyses and provided them to NHC for guidance, feedback from the scientists resulted in numerous improvements and bug fixes, and many suggestions have been cataloged for future incorporation. Needed improvements in aircraft recon data delivery for timely availability over the network, aircraft sampling strategies, and other data flow issues have been identified and need to be addressed in cooperation with NHC and CARCAH in order to meet future milestones. In October H*Wind won the award for "Best Technology Transfer to Operations" at the NOAATech 2002 Conference in Silver Spring MD.

1. JHT Training sessions:

7/25 with Miles Lawrence (Shirley Murillo and Sonia Otero) Miles conducted an analysis of Dahlila in the Eastern Pacific and discussed the analysis with the duty hurricane specialist (Jack Beven).

7/31 with James Franklin (Shirley Murillo, Mark Powell and Sonia Otero)
We gathered these suggestions, some of them have been implemented:

8/17 With James Franklin (Jason Dunion) Used HP workstation to do an 18Z analysis on Chantal.
Problems were discussed involving inconsistencies between wind radii plotted on H*Wind analyses and those calculated in the automated significant wind radii box that appears in the upper left corner of all H*Wind analyses. This problem was traced to two causes:

- There was an insufficient analysis output grid spacing that led to the inability of the grid to resolve some of the significant wind radii correctly. Grid resolution was later increased, which corrected the problem
- The automated calculation of significant wind radii was being based on the storm center determined objectively by the H*Wind analysis rather than on the NHC Hurricane Specialist's chosen storm center (based on the H*Wind storm track). This was later corrected.

8/21 With Miles Lawrence (Mark Powell) Used HP workstation to examine data from Chantal, do analysis, and examine Post Script analysis file. Miles followed the draft users guide "H*Wind for Dummies" available from our web site at http://storm.aoml.noaa.gov and indicated that he just needed some hands on time to get more familiar with the application.

James Franklin requested an additional training session after Hurricane Iris to examine QuikScat, GPS sonde, and adjusted recon data. TC activity interceded with attempts to schedule this session.

JHT PC: Jiing and Brian installed a census PC running Windows in the forecaster area to run H*Wind. Java Web start was installed which allowed the latest version of H*Wind to be run. This worked well for interacting with the forecasters and examining data. Unfortunately, attempts to download a PostScript viewer and SSH client have not been successful yet so the color isotach analysis products cannot be examined. The only feedback available to the screen is the ability to bring in a background field of previously conducted analysis sampled at a 20 km grid.

Suggestions from Hurricane Specialists based on HRD notes from the training sessions

1. Need for a capability to use interpolated storm track positions for analysis start and end times. This is now incorporated but we need to be able to automatically save the storm center fix position associated with the interpolation (not done yet).

2. Some discussion was given to the time label of the analysis. Since the data for an analysis comprise a window of several hours one specialist felt it should not be given a specific time but a time range (the time ranges of all data platforms are contained in the analysis annotation). Another specialist felt that the analysis should be made for specific times corresponding to synoptic times. While there are some advantages for analyses at synoptic times, there are also distinct advantages for a product that visualizes the wind field at the current time or at the time of the advisory. As quantities of real-time platforms and observations continue to increase, time windows will decrease and the wind field "snapshot" will be more representative of current conditions. Our research envisions a graphical product that depicts the current state of the wind field to the public and emergency managers, allowing the user to visualize the wind field at any point in time.

3. Another suggestion was the organization of the wind radii information in the wind analysis product. NHC would like the wind radii box to be organized in the order that they enter the information to their products ie..
from top to bottom:
NE
SE
SW
NW
This suggestion is under consideration.
A few other suggestions have been added to the list developed by HRD scientists near the end of this report.

2. Realtime Analyses conducted by HRD

Up through 15 November, 68 real-time wind analyses were conducted during the 2001 hurricane season. All but four were conducted by HRD scientists. Analyses were placed on

HRD's web site (following a 24 h time lag). Digitized images of analyses and data coverage are available at: http://www.aoml.noaa.gov/hrd/Storm_pages/wind.html
We would like to acknowledge our appreciation to Sam Houston of CPHC for volunteering his services to assist with Gabrielle analyses while visiting HRD during his annual leave.

Atlantic
Allison 2
Barry 6
Chantal 12
Dean 1
Erin 2
Gabrielle 10
Humberto 4
Iris 8
Jerry 4 (concurrent with Iris)
Michelle 15

Eastern Pacific
Barbara 1 (based on QuikScat, GOES winds)
Dalila 1(by Miles based on QuikScat, GOES winds; not on web site)
Juliette 2

Suggestions and improvements based on real-time testing of H*Wind are listed near the end of this report. Weak and hybrid tropical cyclones caused some problems that affected wind radii and thus required immediate attention.

Poorly defined systems caused problems for H*Wind during the first half of the 2001 hurricane season and have led to substantial improvements in H*Wind code. We had difficulties with several storms including Chantal, Dean, and Gabrielle. Several systems had very poorly defined wind centers at flight-level. In such cases the analysis may try to determine a center location based on observations that differs from that provided in the vortex message, leading to errors in the wind radii. Now the wind radii are constrained to be relative to the center position chosen by the analyst (typically a vortex message fix or extrapolation from one). The wind radii also take land exposure into account.

3. Milestones (as per timeline agreed to on 9-19-2001):

Following the agreed timeline, the H*Wind team has fulfilled all of the known requirements for which it was fully responsible due before or on August 31st. These include:

1. Train first specialist with existing system (1 August). (Achieved)

2. Evaluate current system against 20 minute timeliness goal (16 August).
   Conducting QC and an analysis have been completed numerous times within a 20 min time frame. Annotating the analysis to depict the types of data used and other pertinent storm information requires several minutes and can make it difficult for the user to complete QC, analysis, and annotation within the targeted 20 minute timeframe. This relates to the fact that

the analysis annotations are not yet automated and need to be entered manually by the user. Automated annotation will be a subject of work during the off season.

3. Train second specialist with existing system (31 August). (Achieved)

4. Specialists provide feedback, suggest enhancements based on 10-15 real-time or retrospective analyses (31 October).
   Feedback was provided from hurricane specialists, but only four real-time or retrospective analyses were conducted to our knowledge. By October 31st, we were also supposed to have received specialist suggestions, but they are still unknown to us, and thus we have been unable to discuss them, much less prioritize them in the months ahead.

Currently-known requirements based on Pre Season Meeting

1. Complete analysis database storage procedures (1 August) (Achieved)
   When a user "saves" an analysis, it is stored in the database along with a 20 km grid background field along with information on the significant wind radii.

2. Automate observation database updates (15 August) (Achieved)
   A user can update the observations on demand by clicking a button select to have it done automatically (every 10 min).

3. Automate storm track (15 August) (Achieved)
   The vortex message storm fixes are automatically added to the database, but this requires that those data become available to the LDM in a timely manner.

4. Identify data bottlenecks (31 August) (Achieved)

Data formatting
Main issue involves inconsistencies within Air Force HDOB formats and timeliness. At least twice this season (2001), there were format issues that arose:

a) Eastern Pacific, Hurricane Juliette: the new C130 aircraft (AF303) sent data with a new format, that we (HRD Wind group) were not notified about. At the time, it was the only plane out in the storm and this unknown new format prevented us from bringing in the data to H*Wind. Apparently this aircraft was not considered "operational" but, since it was the only aircraft in the storm at the time and was sending vortex messages, it was defacto operational. If any changes are to be made to the format, we need to be notified in order to ensure clean ingestion of data.

b). A more recent incident involved a mis-formatted header sent from AF861's flight into Michelle on 3 November. The header, which is supposed to start with 'SXXX50', began with ']XXX50' for the burst sent containing data from 1901 to 1920 UTC. This caused a data gap in a very critical location near the wind maximum.

Data Timeliness
Of more importance than the occasional format problems, we are still noticing delays receiving aircraft data. Frequently, we are waiting 30-40 minutes or more for a minob burst

in a critical location of the storm, while attempting to meet our analysis deadline. Since HRD is not perceived as a customer of CARCAH, we have little chance to influence the process. It seems that there should be no reason that the Air Force data could not be processed "hands off" so that the datastream of minob bursts and vortex messages could automatically go into digital files (immediately as it enters NHC). In the present system, CARCAH has to "QC" the data and plot out a hardcopy of it, ie. manually send off the data to make it available. This is very time consuming and likely stressful for CARCAH, especially if more than one active system is being flown and can lead to delays in data availability. The present system of making Air Force recon data electronically available is antiquated and cries out for automation. CARCAH could conceivably use H*Wind to QC the data, provided the data can be ingested in a timely manner. Optimizing the data flow to H*Wind (Feb. 02 milestone) will not be achievable until these problems are remedied.

Recon Sampling Strategies

This season and last season there were several poorly organized and hybrid (approaching extratropical) systems. In Tropical Storm Gabrielle, the Air Force recon aircraft increased altitude to 700 mb in the hours preceding landfall on Florida's west coast. Gabrielle was being influenced by a mid latitude feature that caused a large tilt in the center location with altitude. This caused problems, since the storm center locations were based on the flight-level information, but contrasted greatly with the center location suggested by limited surface information (Venice C-MAN indicated a surface center over 20 km to the southeast of the flight-level center. This is a recon sampling issue. In these cases the aircraft observations would have much more value if made at the 850 mb level. If it is not possible for recon aircraft to fly lower altitudes in weak and tilted systems we may have to introduce a method to transpose the surface-adjusted flight-level data to new positions consistent with the surface center.
In Michelle on November 6, aircraft flying at 700 mb or higher levels were finding few observations to justify hurricane strength and sent information that contrasted greatly with GPS dropsonde surface or near-surface information (which validated hurricane conditions). It is important that the aircraft attempt to fly lower altitudes (~850 mb) to more accurately depict these types of systems.

We have noticed that the recon aircraft frequently do not begin to transmit observations at 700 mb or below until the plane is well inside the gale force wind radius, therefore valuable information is not gathered that could help define the outer extent of gale force winds.

The problem is worse when the aircraft are leaving station...they climb to cruise altitude well within the gale force wind radius, again losing potentially important wind radii information. In Iris, the Air Force plane climbed to 500 mb on their way out of the storm, after making an 1119 UTC fix on Oct. 8 and continued to send minobs. Many of these were contaminated by ice and showed up as winds over 150 kt. We do not adjust flight-level observations at altitudes above the 650 mb level, but we do check for a flight-level radius of maximum wind to do our surface adjustments. The ARFES had a 200 kt wind at 51 nm from the center at the 500 mb level, which was used by our new surface adjustment routine as the Rmax. The actual Rmax was 3 nm and 126 kt. We have since incorporated a check for Rmax dependent on aircraft altitude.

Iris and Michelle (in the W. Caribbean) were tight storms that showed the need for obtaining data with a higher time/radial resolution than the current minob data. Unfortunately, since the peak 10 sec data do not have position information, they cannot be accurately plotted. CARCAH is sometimes overwhelmed with the 30 s "minob" data, so a change to 10 s would not go over well with them, but it would certainly help to document these small intense systems. If obtaining 10 s "minobs" is not a possibility, we will have to do some careful interpolation based on an algorithm to determine whether the leg is inbound or outbound. We would also need to consider a tool to decimate the graphical plotting of high frequency observations in H*WIND.

Data bottlenecks (continued)

Data Availability

METAR
For Iris we were missing METAR data from Belieze, Guatemala, Jamaica, Cuba, all the eastern Caribbean Islands, and Honduras. We only had data from Mexico and Grand Cayman, Puerto Rico, the USVI, and one island in the Northern chain of the Caribbean east of the USVI. The cause of the problem in getting this missing METAR data is still unknown. Most of the stations appear in our table, but quite a few do not appear to be coming in over the LDM server. Nick needs to get together with Brian to diagnose the problem in the LDM.

Near-IR GOES cloud drift winds
Jason Dunion (working in cooperation with Chris Velden at U. Wisconsin CIMSS) was able to develop a new method for determining cloud-drift winds during night hours using the near infrared channel from GOES-8 and 10. These data have been available since mid season and are proving valuable in determining the gale force wind radii. Jason is also working to implement solutions for cloud-drift winds over land. This work is supported by HRD and NESDIS funds.

QuikScat, TRMM, and SSM/I
With the assistance of Paul Chang at NESDIS we have had access to QuikScat wind vectors including rain-flagged vectors (throughout the season), SSM/I (throughout the season), and TRMM microwave radiometer surface wind speeds (late in the season).

Work is in process to ingest de-aliased QSCAT data. Nick Carrasco and Jason Dunion will work with Jiing's group. We would like to be able to bring these wind vectors into H*Wind and then allow the user to view all the vectors and de-alias them on the fly based on the user defined storm center and a user specified or default criterion (based on some wind directional range either side of tangential...say within 45 degrees either side as a starter). This technique should provide much better wind solutions than those currently available to us (often limited by the influence of the AVN model's location of the storm). We think this technique could reduce the wind solutions to one or two per measurement location. If there are two solutions for a QuikScat wind vector and there is no additional method to determine which one is correct (other than comparing to neighbors from other platforms) the analysis could use both observations. This work is supported by separate NESDIS funding.

Automatic exposure correction of ASOS Data
We can bring ASOS data into H*Wind, but the exposures vary quite a bit, requiring that the

wind data be corrected. Automatic adjustment of exposure-documented ASOS stations to open terrain still needs to be completed. There are currently over 200 photo-documented stations that are displayed on NCDC's web site through our USWRP project with the local WFO's and NCDC. The photos of these sites all need to be carefully examined to determine each site's roughness length for 8 azimuth direction sectors. Our post analysis of the landfall of Tropical Storm Barry used these corrected data and worked out very well. This work is not supported by JHT and will probably take a few months to complete during the off season, since we are very short staffed right now.

GPS sondes

For the past couple of seasons, HRD has estimated GPS sonde surface winds by using the MBL wind in the Powell (1980) PBL model. Since the sonde frequently will not reach the surface (and sometimes not even reach 150 m above the surface) in intense eyewall winds, this technique provides a means to estimate the surface wind. We now have three types of GPS platforms:

1) the surface wind if measured (shown at the splash location) "GPS Sfc oceanic",

2) the sfc wind estimated from the MBL (also at the splash location) "GPS oceanic",

3) all the various level information contained in the coded drop message "GPS sonde multilevel". All levels are plotted at the sonde launch location. The user can examine any level with the inspector by choosing one of the tabs. Tabs are presently aligned horizontally. We would like to change this orientation to be more intuitive (ie stacked vertically such that the lowest sonde level is positioned at the bottom of the stack).

James Franklin has identified a GPS sonde reduction algorithm for estimating a sonde surface wind given a "WL150" (average of the lowest 150 m of the sonde) that he would like incorporated that involves a least squares fit. If this becomes a requirement we will need to decode the WL150 group, incorporate the fit equation, and add it as a new observation platform into the database.

Milestones (continued)

5. Implement background field (31 August) (Achieved)

The application presents the user with a list of all analyses stored 24 hours prior to current storm center time. After the user chooses one analysis, the system loads the most recent background field corresponding to that analysis and adjusts its positions to the current storm conditions.

6. Identify user-defined reduction algorithms (31 August) (Achieved pending NHC evaluation)

Two flight-level-to-surface reduction algorithms can be presently chosen by the user. One is the HRD reduction method that assumes that the flight-level wind is equivalent to a mean boundary layer wind and then uses a PBL model (Powell 1980) to produce a surface wind. The second is a new method that accounts for warm core/ eyewall tilt effects on the location of the flight-level wind maximum relative to the surface wind maximum. Comparisons between the flight-level maxima and GPS sonde MBL and surface winds are used to estimate an MBL wind from 700 mb flight level winds and then the Powell 1980 reduction is implemented. If the MBL winds are in excess of 55 m/s, our research (Powell et al 1999) indicates that the Powell 1980 model underestimates the surface wind. Therefore a new method is used which is a quadratic fit of the max GPS sonde surface wind given the corrected flight-level-to-MBL wind. This method will be described in an upcoming paper (Dunion and Powell 2002). Alternative surface reduction algorithms developed at TPC based on the same GPS sonde data are likely to be very similar to the method described above. We recommend that NHC evaluate the method already incorporated in H*Wind. Unless there are significant differences that justify making another method a priority requirement, we would prefer to spend time incorporating other improvements and requirements.

4. Improvements/Suggestions gathered during the 2001 season

Many suggestions were provided following feedback from Hurricane Specialists after training sessions.

Storm Track Subsystem:
* After adding extrapolated fix, change button from "Load" to "Add fix".

* End time normally for synoptic times: 00, 06, 12, 18

* Automate track by default with most recent 6 hours, with default center time = synoptic time closest to current UTC time. Example: if last incoming fix is at 1200z and current UTC time is >
  1500z, then extrapolate to 1800z.

Observations and Analysis Subsystems:
* Scope should allow to change starting and ending times; not just limit based on the latest time.

* It is not obvious what "Load Obs..." button does relative to "Check New Data..." button. Something that conveys that "Check New Data" is a subset of "Load Obs...". (DONE)

* Consistency on inspector: one column with international units; another with British system units.
m/s kts
km nm
(DONE)

* "Cancel" on pop up window asking a reason for flagging, the cancel button should cancel flagging action. (DONE)

* Group Flagging tool: pop up window with all platforms types included in the chosen section.

* Preferences: shorter masts or shafts, about 2/3 or 3/4 of current length. Separate barbs more.

* "Edit Platform Weights" should show default weights. Do not allow 0.0 to be entered.

* Consistent ATCF name like NHC, 'al012001' (no '.'). There is an ATCF function that remembers/renames a storm when it changes from Invest to higher category.

* Analysis Description: it could be smarter to know what was already selected when accessing database.

* Rename to "First (innermost) mesh"

* Streamlines: light-dashed
  Isotachs: solid lines (same convention as color plots)
  Nice to have arrows

* When saving a QCSet, ask if it should be sent to ATCF. (DONE)

* Be able to flag using a circle (radially) as opposed to a rectangle.

HRD scientists conducted analyses and provided frequent feedback to the H*Wind software development team. Many suggestions from the scientists were either incorporated into H*Wind or are on a list for needed enhancements. These are other suggestions were elicited by Mark Powell and Jason Dunion after conducting numerous real-time analyses:

- When clicking ATCF event, show only last 10 fixes.
- Larger font on DataViews panel.
- Extrapolation: use last fix's speed and direction as default.
- Rename "LAND" to "INLAND" (DONE)
- Show only platforms with quantities >0; "Check New Data" should add new platforms too. (DONE)
- Tool bar with icons for "Zoom", "Inspect", etc.
- Remove seconds from UTC time on canvas. (DONE)
- Add WAIT cursor on needed scenarios.
- Add Raw Windspeed line to inspector.
  - By default, query flight-level data all the time (650-1050mb) when querying ocean/land surface
  obs. (DONE)
- "Load Event" to "Load New Event"
- Add button "Update Event" (same functionality as "Update Map" on track)
  - When describing an analysis, provide by default pressure of center fix (if VORTEX); if not VORTEX, then pressure of closest fix in time.
- Eyewall tilt surface adjustment algorithm with all related rules: (DONE)
. Only NOAA and Air Force observations are contemplated.
. The wind observations affected are drawn with an encircled barb head, and
. a comment is added to reflect it has been surface adjusted and whether the eyewall tilt was applied or not.
. When checking for new data, the new aircraft winds will automatically be surface adjusted using the criteria previously selected; i.e., using the previous RMW. One can always go back to aircraft original flight-level values and readjust everything using a new RMW.
Note: We need to make sure the flight level RMW is for data below the default max altitude (~ 650 mb)
  - Give warning when attempting to perform a surface analysis with flight level data that has not

been adjusted. Nevertheless, allow analysis execution to proceed. (DONE)

5. Achievements

Sonia Otero, Nirva Morriseau-Leroy, and Nick Carrasco made presentations at the NOAATech 2002 Conference held at the NOAA facilities in Silver Spring, October 2001. H*Wind received the award for "Best Technology Transfer to Operations" .

Presentations at NOAATech 2002:
A Distributed Real-time Hurricane Wind Analysis System (H*Wind)
Mark Powell, Sonia Otero, Nirva Morisseau-Leroy, and Nicholas Carrasco, OAR/AOML

Publishing HURDAT Stormtrack fixes over the Web
Nicolas Carrasco

Geophysical Database Access Using Oracle9i SQLJ Implementations
Nirva Morisseau-Leroy

Complete abstracts and video presentations are available on the NOAATech 2002 web site:
http://www.noaatech2002.noaa.gov/